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OF
COLORADO, UTAH
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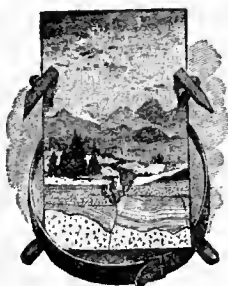
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DEPARTMENT OF THE INTERIOR—U. S. GEOLOGICAL SURVEY
J. W. POWELL, DIRECTOR

ON THE GEOLOGY AND PHYSIOGRAPHY
OF
A PORTION OF NORTHWESTERN COLORADO AND
ADJACENT PARTS OF UTAH AND WYOMING

BY
CHARLES A. WHITE

EXTRACT FROM THE NINTH ANNUAL REPORT OF THE DIRECTOR, 1887-'88



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ON THE GEOLOGY AND PHYSIOGRAPHY OF A PORTION OF
NORTHWESTERN COLORADO AND ADJACENT
PARTS OF UTAH AND WYOMING.

BY -

CHARLES A. WHITE.

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ON THE GEOLOGY AND PHYSIOGRAPHY OF A PORTION OF NORTHWESTERN COLORADO AND ADJACENT PARTS OF UTAH AND WYOMING.

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TOPOGRAPHY OF THE DISTRICT.

Among the many phenomena which are of peculiar interest connected with the geology and physiography of the western portion of our national domain none are more worthy of special attention than those occurring in the region which embraces northwestern Colorado and adjacent parts of Utah and Wyoming. Those which are to be specially considered in this article relate directly to geological structure on the one hand, and to surface drainage on the other, as these conditions now exist in that region; and although the conditions referred to have originated in forces which have acted in intimate relation with one another, they are referable to two different categories of dynamic action that were in part complementary and in part antagonistic; that is, the one category includes those movements of the earth's crust which have resulted in the elevation of plateau and mountain masses, and the other the forces which have effected the disintegration and the immense degradation which the masses so elevated have suffered.

The whole region round about the Uinta Mountains abounds in striking topographical and geological features, the principal of which have been graphically described by Powell;¹ but I have selected for special discussion a few examples possessing unusual interest which pertain to each category, and which occur within a comparatively small district. This district lies within that great elevated portion of the continent which Powell and Gilbert have called the Plateau Province,² and which is one of the grandest fields for geological study that have ever been investigated. But as the plan of this article does not embrace a detailed description of the geology and topography of the district referred to, I shall present only such descriptions and

¹ See *Geology of the Uinta Mountains*, by J. W. Powell; and also *Exploration of the Colorado River of the West and its Tributaries*.

² *Geology of the Uinta Mountains*, pp. 3-7.

facts as are deemed necessary to the elucidation of the special subjects selected.

No part of this district, except a small area immediately adjacent to Green River at the south side of the Uinta Mountains, is less than 5,000 feet above the level of the sea, and a large part of the uneven surface besides the mountainous portion has still greater elevation. Indeed, the land surface of this district which I shall speak of as low when discussing the mountains is only comparatively so, for much of it has a greater elevation above the sea than have some important mountain ranges.

The foot-hills of the Park Range, which is a western portion of the great Rocky Mountain system, lie along the eastern side of the district. Upon its northern border lies the broad region of open country known as Green River Basin; the eastern end of the Uinta Mountain range occupies the western portion, and White River Valley lies along its southern border.

While some portions of the surface of this district consist of open or comparatively plain country, much of it is hilly besides those portions which may properly be designated as mountainous. Besides the eastern end of the Uinta Mountains, there are several other prominent topographic features within the limits of this district. The Danforth Hills rise upon the space between Yampa and White Rivers in the eastern part of the district. Yampa Plateau and Midland Ridge are conspicuous features of the southwestern part; and other more or less isolated elevations worthy of the name of mountains, occur in different portions of it. Among the latter are Junction and Yampa Mountains, which, because of their peculiar structure rather than because of their great prominence as topographic features, are to receive special consideration. They are two isolated mountains lying eastward from and in line with the Uinta Range. They rise abruptly out of the basin or broad valley through a part of which Yampa River flows, and which, for reasons that will be made obvious, I have called Axial Basin.

The principal drainage of the district is effected by Green River, its tributaries, White and Yampa Rivers, and by Snake River, a tributary of the latter. Green River is itself the principal tributary of the Colorado of the West, or more properly speaking, it is the northern portion of that river and ought never to have received another name.

This district is a part of the great arid region of the continent, and therefore the low-land tributaries of the rivers are mostly dry during the summer, which is the only part of the year during which surveys are practicable, mainly because at other times the excess of water in the rivers renders them unfordable. That is, in summer only the main portions of these rivers, and a few branches supplied by perennial springs, contain water, and this is mostly derived

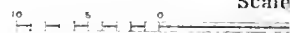


GEOLOGICAL MAP OF A PORTION OF NORTHWESTERN COLORADO

BY CHARLES D. WALSH

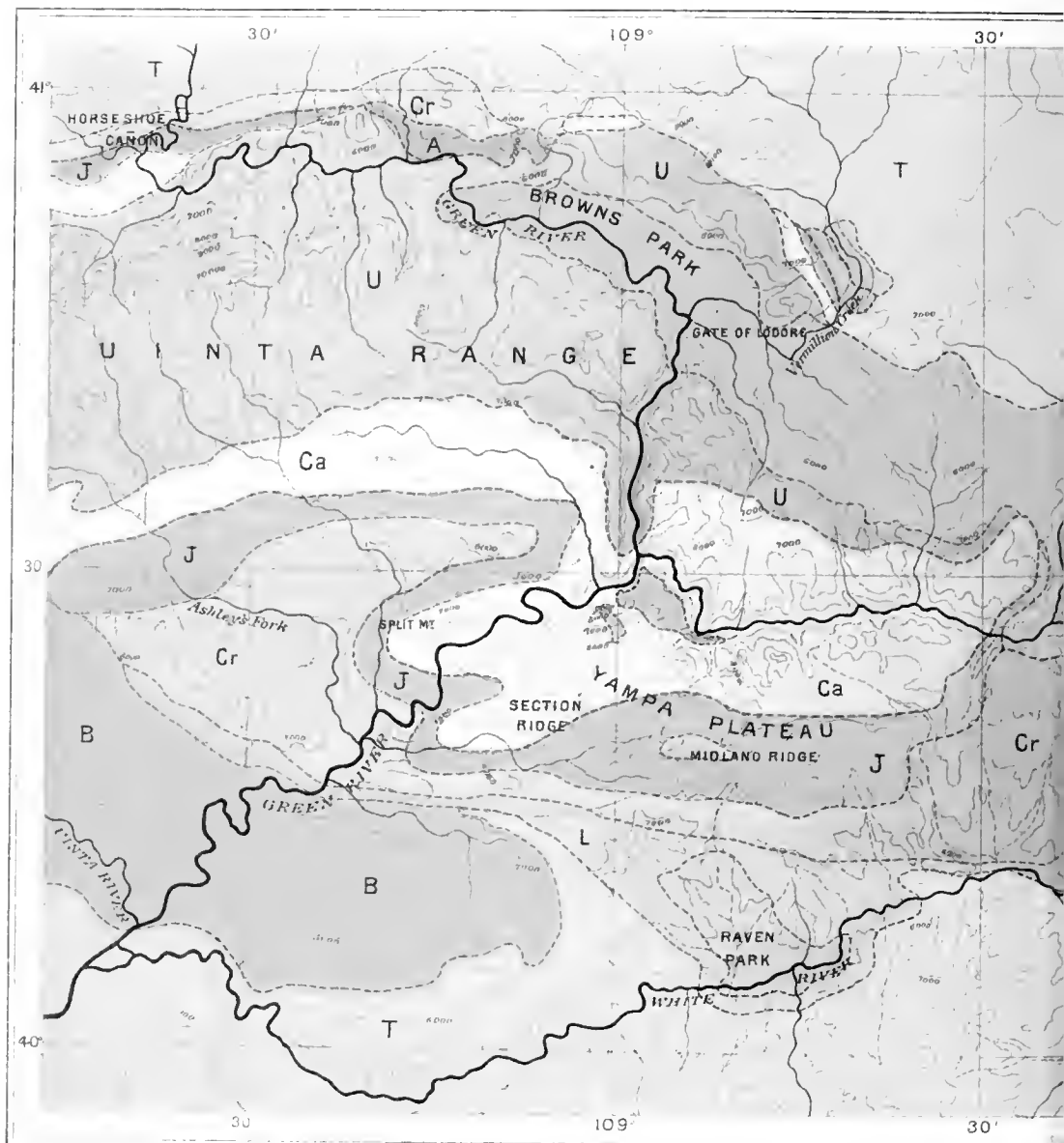
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TERTIARY.

CRETACEOUS.

JURA-TRIASSIC.

BROWNS PARK **B** BRIDGER GREEN RIVER WASATCH. **T**

LARAMIE **L** FOX HILLS COLORADO DAKOTA. **Cr**

J

AND ADJACENT PARTS OF UTAH AND WYOMING TERRITORIES.

A. WHITE.

AND MAPS OF POWELL, HAYDEN, AND KING.

Miles

20 30

,1000 Feet.

NINTH ANNUAL REPORT PLATE LXXXVIII



A. HORN & CO. LITH. BOSTON

1. CARBONIFEROUS. UINTA SANDSTONE. ARCHAEOAN. ERUPTIVE ROCKS.

Ca

U

A

E



from mountain tributaries. Consequently, while active erosion of the general surface is suspended there during a large part of the year, direct corrasion of the river beds is constant. Passing mention may be made of the fact that this constancy of corrasion has prevailed in that region through a long period of time, a part of the results of which are the numerous deep and narrow cañons now found there.

In consequence also of the general aridity of the region during a large part of the year vegetation is sparse upon the lower plain and hilly lands, which are always the drier, and even that of the mountains is not usually sufficient in amount to materially hinder the study of the underlying formations by obscuring them. This condition, together with the rapid removal by erosion during the winter months of the debris resulting from the disintegration of the formations greatly facilitates the study of the geology of that region.

Other important features of this district are its cañons. These will necessarily be referred to, and in part described on following pages. Those of Yampa River, although shorter and less deep than many others, will receive special attention because of their peculiar characteristics, and of their extraordinary relation to Junction and Yampa Mountains, and to the Uinta Range. Besides a discussion of certain of the mountains and cañons of this district, evidence will be presented that the Uinta and Rocky Mountain ranges have important structural relations with each other although their axes are at nearly right angles, and although there are considerable differences between their older rock formations respectively.

Partial descriptions of the mountains and cañons referred to have been published by Powell,¹ King,² and Hague & Emmons,³ and by myself,⁴ but while omitting many matters of great interest, I shall attempt a somewhat fuller presentation of the special subjects selected than has heretofore been published, and try to point out more clearly the significance of certain phenomena which have been observed there.

GEOLOGICAL FORMATIONS OF THE DISTRICT.

As the phenomena which it is now proposed to discuss pertain to the elevation, displacements, and degradation of the great formations of stratified rocks that prevail in the region which embraces the district before designated, it is necessary to give some account of them. The following table comprises a list of these formations, beginning with the latest, together with the estimated thickness of each as they have been measured in the region embracing the eastern

¹ Geology of the Uinta Mountains.

² U. S. Geol. Expl. 40th Parallel, vol. 1.

³ U. S. Geol. Expl. 40th Parallel, vol. 2.

⁴ Annual Report U. S. Geol. Surv. Terr., for 1876.

end of the Uinta Range. Following the list, a description of each formation is given, so far as is deemed necessary for the present purpose:

Table of the Formations.

		Feet.
Cenozoic.....Tertiary	Brown's Park group.....	1,200- 1,800
	Bridger group.....	100- 2,000
	Green River group.....	1,400
	Wasatch group	2,000- 2,500
Mesozoic ...	Laramie group ¹	2,000- 3,000
	Fox Hills group	1,800
	Colorado group.....	2,000
	Dakota group.....	500
	Jura-Trias	2,500- 5,000
Paleozoic...	Carboniferous	3,000- 4,000
	Uinta sandstone	12,000-14,000
Archean.....		

ARCHEAN ROCKS.

The Uinta Mountain range is unlike the Rocky Mountain ranges in not having the crystalline Archean rocks exposed as a central or axial mass. It is highly probable that Archean rocks rose in the axis of the Uinta fold during its elevation, somewhat as they are represented in the generalized section, Fig. 58, and as they rose in the orogenic folds of the Rocky Mountain system where they are very conspicuous. So far as is known, however, they were not sufficiently elevated in the axis of the Uinta fold to have become bared by the erosion which has given the Uinta Mountains their present form. The only rocks of this age which are exposed to view in the district under discussion, or that are known to be exposed in any part of the fold, are not in its axis; they occupy a small area upon its northern flank, not far from the eastern end of the main fold. The fact that the Uinta quartzite rests unconformably upon these Archean rocks suggests the probability, first mentioned by Powell,² that the latter were raised by a circumscribed uplift in Archean time; and that they constituted an island which remained such while at least the earlier part of the Uinta strata were being deposited. In the subsequent elevation of the great fold it is only a part of this island portion of the great Archean mass that has been brought to view.

While these rocks are probably geologically equivalent with the Archean rocks of the Rocky Mountain ranges, it is worthy of remark that those of the Uinta Mountains present considerable lithological differences from those of the Rocky Mountain system. That is,

¹ See remarks with foot-note reference on pp. 690, 695, 696.

² See *Geology of the Uinta Mountains*, p. 139.

although they both contain similar component minerals, their proportions in the rocks of the two ranges are very different. A white or light gray quartz is so largely prevalent in the Uinta Mountain Archean, and the other minerals are in such small proportion, that Powell designated it as a quartzite in the name which he gave to the formation.¹

These rocks not having been observed in the axis of the Uinta fold, it will not be necessary to take them any further into consideration now, nor when estimating the amount of vertical displacement of the strata entering into that fold, except to regard them as constituting the floor of the Uinta quartzite.

UINTA SANDSTONE.

This great formation extends from end to end of the Uinta range of mountains and constitutes a large part of their bulk. It is also found in the isolated upthrust mountains just beyond the eastern end of the range which have already been mentioned; but it has not been recognized as such in any part of the Rocky Mountain system, nor elsewhere northward, southward, or eastward from the Uinta Range. This is somewhat remarkable in view of the uniform character of the formation, and of its great thickness in that range which, according to Powell, reaches a maximum of 14,000 feet.

This formation has usually a brown, or dark ferruginous color, and the ordinary regularly bedded character of sandstone. In some places it has nearly the compactness of true quartzite, but usually its hardness is that of ordinary firm sandstone. In some places soft and shaly layers are found, but these are exceptional. As a whole, the general lithological character of the formation is readily recognizable; and it has considerable uniformity throughout its geographical extent, and from the lowest to the uppermost known strata.

Much difference of opinion has prevailed as to the true geological age of the Uinta Sandstone. King, who gave it the name of Weber Quartzite, states that it is of Carboniferous age;² in which view Hague and Emmons concur.³ Powell referred it provisionally to the Devonian;⁴ Marsh was disposed to regard it as belonging to the Silurian,⁵ at least in part; and Hayden was of the opinion that it ought to be referred to the Lower Silurian.⁶

¹ See *Geology of the Uinta Mountains*, p. 137.

² *U. S. Geol. Expl. 40th Parallel*, vol. 1, pp. 152 and 240.

³ *U. S. Geol. Expl. 4th Parallel*, vol. 2, pp. 290, 323, and 452. In a foot-note to page 99, however, they indicate some doubt as to the correctness of their opinion as first formed.

⁴ *Geology of the Uinta Mountains*, p. 141. But it is proper to state that I have personal knowledge of the fact that for the past ten years Major Powell has regarded this formation as of pre-Cambrian age.

⁵ *Am. Jour. Sci.*, 3d series, vol. 1, p. 193.

⁶ *Ann. Rep. U. S. Geol. Surv. Terr.*, for 1870, p. 50.

Whatever may be the geological age of the Uinta Sandstone, it is certain that the undoubted Carboniferous rocks of this district rest directly upon it; and, according to Powell, there is in many places distinct unconformity between them. It is also true that within this district no other rocks than the Archean have been found beneath the Uinta Sandstone.

CARBONIFEROUS.

The conditions attending the deposition of the Carboniferous series in that far western region were different from those which attended the deposition of the rocks of the same age in the region drained by the Mississippi; and the full series in the two regions respectively are therefore differently divided. In the region of the Uinta Mountains the Carboniferous series has been divided into three nominal formations, mainly upon lithological grounds, all of which are strictly conformable with one another. The series in this region consists in large part of limestones, but in part of sandstones, all of which usually are regularly bedded, and most of which are compact and hard. Shaly or softer strata rarely occur among them, and coal, which so distinctly characterizes the series elsewhere, has never been discovered among its strata there. Because of this strict conformity of the three nominal formations of the Carboniferous series with one another in this region, and the generally firm character of all the strata composing them, the whole series will be treated as a single unit in the following discussions.

Attention should here be called to the fact that the Paleozoic strata, that is, those of the Uinta and Carboniferous formations, consist as a whole of much harder rocks than those of the later formations, descriptions of which now follow.

JURA-TRIAS.

Resting conformably upon the Carboniferous in this district there is a series of sandstones which have usually been regarded as of Triassic age, but it is probable that the lower portion ought to be assigned to the Carboniferous series. These sandstones consist of yellowish, moderately firm strata above, of yellowish softer strata below; and between them a thick mass of bright red or brownish-red strata, most of which are moderately firm. The Triassic age of all of them except the lower portion just mentioned, has rarely been questioned; but the strata of that portion being usually barren of fossils, its geological age has not been determined with as much accuracy as could be desired.

Upon the Triassic sandstones comes a small series of beds which are usually referred definitely to the Jurassic. They consist of soft,

variegated bad-land¹ sandstones, with occasionally harder layers; and near the base of this comparatively thin series of strata, a few feet in thickness of sandy, shaly, or often calcareous, fossiliferous layers, are usually found. This Jurassic portion of the Jura-Trias series is hardly more than one-fifth of the whole in thickness, but its distinguishing characteristics are quite uniform over a wide geographical area.

CRETACEOUS.

The full Cretaceous series in this district, exclusive of the Laramie, reaches a thickness of 4,300 feet; and the Laramie has here a thickness of 2,000 to 3,000 feet additional. In accordance with the views expressed by me on a former occasion² I here place the Laramie among the Cretaceous formations. This arrangement is the more desirable in the present case because the stratigraphical and not the paleontological relations of the formations are discussed. That is, in these discussions prominence is necessarily given to the fact that not only does the Laramie group rest conformably upon the marine Cretaceous, but the former group is fully involved with all the formations earlier than itself in all the displacements which are mentioned as having occurred in this district, while the later formations were not thus fully involved.

The Dakota Group, the lowermost of the Cretaceous series in this region, and the equivalent of No. 1 of the Upper Missouri section of Meek & Hayden, here presents nearly the same general characteristics which it possesses throughout the great Rocky Mountain region. The upper portion consists of yellowish or brown rough sandstone, the middle portion of variegated sandstone, and the lower portion of irregularly bedded pebble conglomerate. The strata are generally firm, and their escarpments prominent.

The Colorado Group, the equivalent of Nos. 2 and 3 of Meek & Hayden, consists in this district of dark colored argillaceous shales, and clayey and sandy strata, with occasional layers of moderately firm sandstones. All these strata are so soft that they seldom appear in escarpments; and because of the facility with which they are eroded they have given place to certain of the basins and broader valleys.

The Fox Hills Group, the equivalent³ of Nos. 4 and 5 of Meek &

¹ The Mauvaises Terres or Bad-Lands of the West are usually covered with debris which is often so soft as to yield to the pressure of the foot; but the material before erosion is almost always a soft earthy sandstone, designated as bad-land sandstone.

² See White, C. A., on the relation of the Laramie Group to earlier and later formations: *Am. Jour. Science*, 3d series, Vol. 35, pp. 432-438.

³ Since this article was written I have adopted the name Montana Group proposed by Mr. Geo. H. Eldridge for the equivalent of Nos. 4 and 5 of the Upper Missouri section. See *Am. Jour. Sci.*, Vol. XXXVIII, Oct. 1889, pp 313-321.

Hayden, here presents some differences in lithological character from that which it possesses in other districts. The upper part consists mainly of the more common, somewhat soft sandstones, but the lower portion is so largely made up of soft, sandy, and argillaceous shales, similar to the shales of the Colorado Group, that in the absence of characteristic fossils it is difficult to distinguish the two formations apart where they are found in contact.

The Laramie Group consists mainly of sandstones and sandy shales. The sandstones, while not often very hard, are frequently so firm that they form abrupt escarpments; and they also form prominent hogbacks when tilted at a high angle. The absence of true marine fossils in this great formation, and the presence throughout its wide geographical extent of such forms as now characterize fresh and brackish waters is worthy of notice. These facts indicate that the formation was deposited in a great inland sea, or one which was largely cut off from the open ocean by land barriers which were elevated at the close of the Fox Hills epoch. These barriers probably did not reach any considerable height above the sea; or at least their elevation was evidently not a part of the orogenic movements which began at the close of the Laramie period, and resulted in the production of the Uinta, and other great folds upon a broad and rising continental area.

TERTIARY.

The Tertiary strata of this district are all of fresh-water origin, and are divided into four groups. The three lower ones are usually referred to the Eocene without hesitation; while the upper one is sometimes referred to the Eocene, sometimes to the Miocene, and sometimes to the Pliocene. The three lower groups are strictly conformable with one another, and the lowest one appears in this district to rest conformably upon the Laramie, where the contact has been observed. The upper or Brown's Park group, however, is conspicuously unconformable with the other Tertiary formations, as well as with all the other formations with which it is found in contact.

The Wasatch Group, the equivalent of the Bitter Creek group of Powell and of the Vermillion Creek group of King, consists in this district of alternating harder and softer sandstones below, and of bad-land sandstones above.

The Green River Group consists of coarse, irregularly bedded sandstone above, and sandy and calcareous, with occasionally carbonaceous, layers below, which are generally thin bedded, and occasionally shaly. The maximum thickness of both divisions in this district is only about 1,400 feet, which is about equal to the full thickness that this formation is known to have elsewhere.

The Bridger Group reaches a thickness of only about 100 feet in this district, but northwestward from this district it has been

observed to reach a maximum thickness of about 2,000 feet. It consists mainly of bad-land sandstones, but sometimes the layers have considerable firmness.

The Brown's Park Group is regarded as equivalent to the Uinta group of King.¹ The latter name was given by King to those strata of the group that occur on the south side of the eastern end of the Uinta range; but he did not recognize those upon the north and east sides as being different from the Green River group.² The southern portion presents a reddish or yellowish ferruginous aspect; while the northern and eastern portions have throughout an unusually light color. This difference in color is perhaps due to the derivation of material from the red Triassic sandstones in the one case, and from the light-colored Bridger and Green River groups in the other.

The Brown's Park group consists mainly of sandy material, usually fine grained, with occasionally gravelly strata. The strata are sometimes evenly bedded and firm, but they are often irregular and friable; and they are frequently incoherent where exposed at the surface. Because it rests unconformably upon all the other formations with which it comes in contact, it obscures the underlying geological structure in numerous places; but seldom to such an extent as to leave the real character of the structure in doubt.

Besides the formations described in the foregoing paragraphs there are certain later surface accumulations; but as they have no necessary relation to the special subjects of this article they are not represented upon the accompanying map; and they are mentioned here only by name. They are the Bishop's Mountain Conglomerate (= Wyoming Conglomerate of King), the local drift derived, apparently by glaciation, from both the Uinta and Park ranges, and the Quaternary deposits of the river valleys. Eruptive rocks are also found in the eastern part of the district, as represented upon the accompanying map; but a description of them is not deemed necessary for the present purpose.

DISPLACEMENTS.

The displacements which these formations have suffered in this district are numerous, and some of them are of great vertical extent. They are mainly in the form of folds or of more circumscribed uplifts, and of more or less conspicuous tiltings. The principal displacement within, or that reaches within, this district is the great Uinta fold.

¹ Not the Uinta group, or, Uinta quartzite of Powell (op. cit.).

² See Atlas U. S. Geol. Expl. 40th parallel, Map II, east half. Also compare with the map accompanying this article, and with map B, of atlas of Geology of the Uinta Mountains.

THE UINTA FOLD.

This fold has usually been described as having its eastern end terminating abruptly in northwestern Colorado. As a conspicuous fold it does so terminate; but continuous with its axis to the eastward there is a long gentle anticline which reaches by a broad curve to the foot-hills of the Park Range, and which I regard as a continuation of the Uinta fold. I therefore divide the Uinta fold into two portions, namely, the main portion or the Uinta fold proper, and the inceptive portion of the same. For convenience of description I shall so designate them in this article.

Both Powell¹ and King² have shown that the Uinta fold is composed of a series of formations of stratified rocks of great thickness, which have all been elevated together along an approximately east and west axis. The fold proper is about one hundred and fifty miles in length, and from thirty to forty miles in width at the extreme limit of the upturned strata at either side. Its western end is blended with the Wasatch Range in Utah, which it meets at nearly right angles. Its eastern terminus is about thirty miles within and east of the western boundary of Colorado, and about the same distance from the northern boundary. Its axis is not quite straight, the maps of its surveys showing gentle and somewhat irregular meanderings. One of these gives its eastern end a gentle curve a little to the south of its general course, which brings it into line with the curved axis of the inceptive portion of the fold.

This great fold is remarkable for its simplicity and its peculiar characteristics, as compared with the other orogenic displacements which have occurred in that great region; that is, while its western end blends with the Wasatch Range, and its eastern end has structural relation with the Rocky Mountain system, the great fold, as a whole, has certain characteristics peculiarly its own, and it has also few lateral complications. It is true there are certain minor plications adjacent to the range; but, with the exception of the Yampa Plateau³ fold, these are comparatively small and inconspicuous.

It is out of the formations which were brought up in the great Uinta fold that the mountain range, as we now know it, has been carved. This carving has been accomplished by the ordinary process of erosion which is, and always has been, in constant action upon the surface of the earth; but it has here been effected upon a scale of such magnitude that the present majestic peaks may be properly regarded as only shreds of the enormous mass which has been uplifted there. Some of the higher peaks of the range have now a

¹Geology of the Uinta Mountains.

²U. S. Geol. Expl. 40th Parallel, vol. 1.

³Yampa Plateau must not be confounded with Yampa Mountain. Separate names for each would be used here if it were deemed expedient to change either of them after their long publication and use.

height of more than 7,000 feet above the general surface of the surrounding region; and the elevation of the region itself is so great that the summits of those higher peaks are more than 13,000 feet above the level of the sea.

Powell has shown that the Uinta fold is of a peculiar type,¹ being characterized by an abrupt upward flexure of the strata at either side, which in some places is a true fault, while between the two abrupt side flexures the fold is broad, and its convexity comparatively gentle.



FIG. 57. Diagram representing the Uinta type of displacement.

The accompanying diagram (Fig. 57) copied from Powell, illustrates this peculiar form which he designated as the Uinta type of displacement. This peculiar type characterizes not only the main fold, but it is recognizable in some of its subordinate uplifts; for example, in the midland and Yampa Plateau folds.

Before proceeding with a description of the great fold it is proper to refer to some other matters which are of general importance in this connection. Attention has been called to the fact that the Carboniferous and Uinta Sandstone formations are mainly composed of hard rocks. The later formations, from the Jura-Trias to the Laramie inclusive, although their strata are often firm, are, as a whole, composed of softer rocks, many of them yielding readily to disintegrating action. The same may be said of the three lower Tertiary formations, while the upper one, or Brown's Park group, is in still larger part composed of friable materials. It should be further mentioned that all these softer formations are mainly composed of siliceous sand.

These facts are mentioned here because of their bearing upon the question of the origin of the present remarkable topographic features of this region. One may readily understand that if the earlier formations had consisted of softer rocks than the later ones, the topographic features resulting from their displacements and from the erosion which the whole have suffered, would have been very different from what they now are. Again, one quickly reaches the conclusion that it is the siliceous materials of the softer formations that have been made the instrument of corrasion of the harder rocks, which fact will presently be discussed.

Other conditions being equal the rapidity and extent of disintegration and erosion would depend largely upon the varying hardness of the rocks thus effected, but it is not always the case that the softer

¹ Geology of the Uinta Mountains, p. 17.

rocks have suffered most in this respect. In fact, the hardest rocks have yielded to such action, and to the more direct action of corrasion, to a surprising extent, and in this district numerous examples

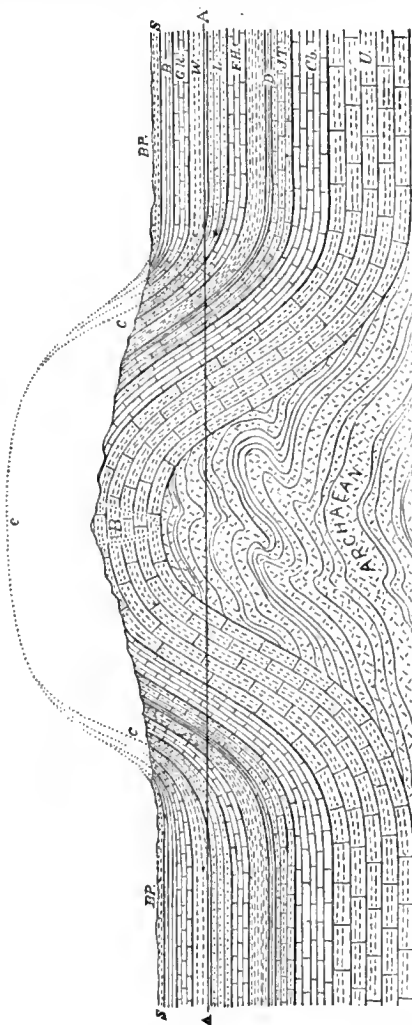


FIG. 58. A generalized transverse section of the Uinta fold.

The irregular line, S. S., represents the land surface, and the straight line, A. A., the sea level. The dotted line at either side of B. represents the depth to which Green River has cut its cañon in traversing the Uinta Range. The dotted lines above the surface line represent those portions of the formations which have been eroded, and the extent to which they would have been elevated in the fold if they had suffered no erosion.

The dotted line, e. e., is continuous with the top of the Laramie group. This indicates that all the formations beneath that line were fully involved in the fold; while the other dotted lines, which lap upon either side, represent the eroded portions of the four fresh water Tertiary formations which were successively less and less involved in the fold as the elevation progressed.

The initial U. indicates the Uinta Sandstone; C. B. indicates the Carboniferous; J. T., the Jura-Trias; D., the Dakota group; Co., the Colorado group; F. H., the Fox Hills group; L., the Laramie group; W., the Wasatch group; G; R., the Green River group; B., the Bridger group, and B. P., the Brown's Park group.

are found which seem to show that they have offered as little resistance to erosion as the softer rocks have done, and in some cases, at least, they seem to have offered less resistance to the corrasive action of rivers than have the softer rocks. The reason for making this latter suggestion will be made apparent in the following paragraphs which refer to river cañons.

It is the softer rocks which have yielded the instrumental material for the corrasion of the cañons in the harder formations. If there

had been no thick formations of hard strata there could have been no narrow, deep cañons, and if there had been no extensive formations of friable siliceous rocks in the same or adjacent district the cañons could not have been cut for the want of the proper instrument. In short, and as has already been mentioned, it is sand, together with other rock fragments, that has served as the instrument of corrosion, while the moving water of the rivers has served as the vehicle for transporting the instrument, and as the medium for applying the power by which the corrosion was accomplished.

Let us now return to a consideration of the great Uinta fold. The study of the present geological structure of a region enables us to reach important conclusions as to the past geological history of that portion of the earth of which it forms a part. Such a study of the region round about the Uinta Mountains shows that the formations there were not all equally involved in the great fold. The present condition of those formations and their relation to one another, show that all of them, from the Uinta sandstone to the Laramie inclusive, were equally involved in that fold, while the relation of the Tertiary formations to those older ones, show that these were only partially involved in it. These relations of the formations to one another, and to the great fold, are graphically illustrated by the accompanying generalized section of the Uinta fold. (Fig. 58.)

From the foregoing, and other correlated facts, the inference is drawn that the elevation of the great Uinta fold was begun immediately upon the close of the Laramie period, and before the first of the fresh-water Tertiary strata were deposited; and that it was nearly complete before the deposition of the Brown's Park group; the latest of the fresh-water Tertiary series. Other facts already referred to, indicate that the waters in which the Laramie group was deposited rested at a level which was little, if any, above that of the open sea; and the character and present condition of the Tertiary formations show that they were successively deposited at respectively different heights above that level. That is, they were deposited in great lakes, the existence, extent and elevation of which were respectively determined by the varying configuration of the general land surface as elevation and degradation progressed.

The facts which have been presented show that the orogenic movements¹ which have resulted in the production of the Uinta and other mountain-making folds were approximately synchronous in their origin, and coeval as to time-limits of their duration, with the epirogenic movements by which the great continental area upon which those folds rest reached its present elevation.¹ These con-

¹ Certain epirogenic movements must necessarily have taken place to form the barriers by which the Laramie sea was cut off from the open oceans. Local unconformity among the Laramie strata, which has been observed near the top of the group in southern Wyoming, indicates that certain other premonitory movements took place before the Uinta fold was well defined.

clusions, and the facts upon which they are based, are of importance in estimating the amount of vertical displacement which has taken place in the Uinta fold, because they constitute the data by which we determine the upper and lower limits of the series of formations which were wholly involved in it, and which alone need to be considered in that immediate connection.

In the case of many mountain ranges it is difficult to estimate the amount of vertical displacement which has taken place in their elevation. But the Uinta Range and its foot-hills being composed almost entirely of a series of at least approximately conformable formations of stratified rocks, the thickness of each of which has been ascertained, an estimate of the amount of vertical displacement there may be made with a good degree of confidence in its general accuracy.

The formations later than the Laramie not having been involved in the beginning of the uplift, and the Archean rocks not being exposed in the heart of the Uinta Range, both are excluded from the estimate here given. This estimate is based upon the ascertained thickness of each of the formations from the Uinta sandstone to the Laramie, inclusive, the elevation above the sea of the lowermost observed strata of the Uinta sandstone, and upon the fact, as assumed, that the top of the Laramie was little, if any, above the level of the sea when the upward movement of the fold began.

In making this estimate I have thought best to use the minimum thickness of each formation as given in the foregoing table, lest I should appear disposed to exaggerate a statement of facts which are obviously so remarkable. The aggregate thickness of the formations from the Uinta sandstone to the Laramie, inclusive, is thus found to be 23,800 feet. Add to this 5,000 feet as the height above the sea at which the lowermost strata of the Uinta sandstone have been observed, and, we have an aggregate of 28,800 feet, or about five and a half miles.¹

It is of course not to be understood that even the uppermost of the strata of the uplifted series ever reached a height above the level of the sea at all approximating the full amount of vertical displacement. In fact, we have no reason to suppose that any portion of the Uinta Range ever attained a much greater height than the higher peaks now have, because erosion of even the hardest rocks closely balances elevation after certain heights are reached.

¹Accepting Powell's statement as to the marked unconformity between the base of the Carboniferous and the top of the Uinta sandstone, and his views as to the pre-Cambrian age of the latter, geologists will readily perceive their great significance. But these facts and conclusions do not necessarily affect the estimate here given of the amount of vertical displacement in the Uinta fold. They point to a great blank in geological history as regards the region here discussed, the closing epoch of which was long anterior to any of the movements and displacements described and referred to in this article.

The readier yielding of the softer than of the harder rocks to disintegrating and erosive action under like conditions has already been referred to. This fact has seeming exemplification in the presence of the older and harder rocks in the higher mountains in this district, and the removal of the later and softer ones from the more elevated portions of the uplifts, which must necessarily have once rested there. But it must be borne in mind that it would have been impossible for even the harder strata to resist the constantly active forces of degradation, at the great heights to which the softer ones would have been carried, if they had not been removed by erosion while they were being elevated. With these explanations we will now consider certain other topographic and structural features of this district which it is the object of this article to discuss.

The eastern terminus of the Uinta fold proper is by a dip of its greatly elevated strata, which is quite as abrupt as it is at the sides of the fold. This terminal dip has a broadly sweeping semi-elliptic trend, which is marked by the upturned edges of the later formations that were involved in the fold, as they also mark the trend of the dip at either side. These later formations having suffered complete erosion from a broad space on either side of the axis of the fold, the present mountains are found to be composed of the earlier formations almost alone, while the characteristic lateral dips are mainly observable in the later ones.

The semi-elliptic form of the trend of the upturned strata is due to the preservation of the type of uplift of the fold, even to its very end. The upturned strata which mark that trend, however, are to a considerable extent obscured from view upon the northern side. This is in part due to a remarkable down throw of the strata which were there involved in the fold, as has been shown by Powell,¹ and in part to the presence there of the later Tertiary formation which bears the name of the park, as already described.

The termination of the great fold by a sudden dip while preserving nearly its full width is worthy of remark, because it shows that the main portion of the fold does not pass gradually into the inceptive portion. This condition might perhaps be regarded as an indication that the latter portion is not really a continuation of the former if it were not true that similar conditions are observable in the case of other displacements which are immediately connected with both the great fold and its inceptive portion. But this subject will be further considered in following paragraphs.

THE YAMPA PLATEAU, AND OTHER SUBORDINATE FOLDS.

Before proceeding eastward, along the inceptive portion of the Uinta fold, however, let us briefly consider three subordinate up-

¹Geol. Uinta Mountains, pp. 208, 209.

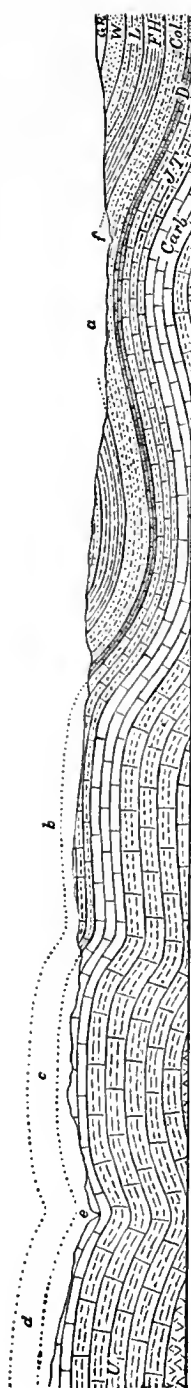


FIG. 59. Section across Raven Park, Midland Ridge, Yampa Plateau, and a portion of the main Uinta Range.

a, Raven Park uplift; b, Midland fold; c, Yampa Plateau fold; d, a portion of the main Uinta fold; e, Yampa River; f, White River; U, Uinta sandstone; Carb., Carboniferous; JT, Jura-Trias; D, Dakota group; Col., Colorado group; FH, Fox Hills group; L, Laramie group; W, Wasatch group; GR, Green River group.

lifts which lie adjacent to the southern side of the eastern end of the main fold and another, the Danforth Hills uplift, which lies adjacent to the south side of the inceptive portion of that fold. Two of the first mentioned uplifts are in the form of somewhat short folds which lie closely adjacent to each other, as well as to the main fold, with the axis of which the axes of these two subordinate folds are approximately parallel. They are designated as the Yampa Plateau and the Midland folds, respectively. The third one, which I have called Raven Park uplift, lies toward the south near to, but not adjoining, the others. It is approximately oval in outline, has a less vertical displacement than the others, and the direction of its longer diameter is nearly northwest and southeast.

It will be observed that these subordinate folds are clustered together at the south side of the eastern terminus of the main portion of the great fold; that the two larger ones terminate suddenly, especially at the eastern end, as does the great fold; and that beyond these abruptly terminating ends there are no indications of a continuation of their axes.

The lateral relation of these subordinate folds to one another and to the main fold is shown in the accompanying section, Fig. 59, the line of which is across them, and approximately upon the meridian of $108^{\circ} 50'$.¹

The topographic feature known as Yampa Plateau is so closely blended with the mountains of the Uinta Range that it may properly be regarded as a part of the same. It includes the western portion of the Mid-

¹The section F. F., which is given at the bottom of the map facing page 60 of Ann. Rep. U. S. Geol. Surv. Terr., for 1876, was intended to represent the same strata and their displacements which are represented in this figure. That section, however, is incorrect, and was published without an opportunity having been given the author of the report to correct it.

land, as well as that of the plateau fold, but it does not extend to the eastern portion of either of them. My present object, however, is to refer to the folds as a part of the series of displacements which it is the special object of this article to consider, rather than to describe topographic features.

Yampa Plateau fold is about 40 miles long from its eastern to its western terminus. Its vertical displacement has been so great as to bring up the Carboniferous rocks, which, by erosion of the later formations, are exposed at the surface along its whole length, leaving those later formations upturned at the ends of the fold. The eastern end terminates as suddenly as that of the main fold by a similar broadly sweeping dip of its strata, and at a point only a little further westward than the terminus of the main fold. Its western termination is by two prominent spurs, called respectively Split Mountain and Section Ridge. Unlike most spurs which are projected from mountain ranges, these are quite regular in structure. Each is closely like the other in this respect, as well as in their dimensions and in the extent of the vertical displacement which their strata have suffered. The central portion of each is composed of Carboniferous rocks, which are continuous with those of the main mass of the plateau, while the Mesozoic rocks are upturned all round their base as they are around the other uplifts in this district.

The axis of the Split Mountain spur extends nearly 15 miles almost due west from the body of the plateau; but the later formations involved having been greatly eroded, the spur as it now exists is much shorter. There is a narrow synclinal valley between it and the main fold; and a shorter more open one between its southern side and Section Ridge, both of which communicate with the open country which stretches away to the southward. The Section Ridge spur is somewhat shorter than the other, although the axial length of this as well as of the other is greater than the breadth, and the direction of its axis is a little to the south of west. The strata involved in these spurs dip regularly around the base of each, and thence trend away at the base of the plateau on the one hand, and that of the Uinta Range on the other. The regularly curved dip around the distal end of each spur is so marked a geological feature that I have applied to it the term *partiversal*¹ dip.

The vertical displacement of Midland fold is less than that of Yampa fold, so that the Triassic rocks occupy the greater part of its surface, the Carboniferous strata not having been brought to view. Its eastern terminus is by a broad sweeping dip, like that at the east-

¹A *quaquaversal* dip, as the term is usually applied, is in all directions from a given point. A *partiversal* dip is around the vanishing end of an anticlinal axis. The region round about the Uinta Mountain Range contains numerous examples of *partiversal* dip.

ern end of Yampa Plateau fold, and it retreats a little to the westward, as the last named fold does with relation to the terminus of the main fold.

The Danforth Hills, which have already been mentioned as occupying a portion of the eastern part of this district, rest upon the comparatively gentle fold, or uplift to which I have given the same name. This fold lies adjacent to the southern side of the inceptive portion of the Uinta fold and within the broad curve which it makes

in its extension from the Uinta to the Park Range. Its lateral position with relation to the inceptive fold is indicated by the section, Fig. 60.

These subordinate folds have been briefly described here that they may be referred to in connection with the discussions yet to be made. Let us now return to the eastern terminus of the main portion of the Uinta fold and proceed eastward along its inceptive portion. The axis of this portion of the fold passes along the broad valley which I have called Axial Basin, and thence by a broad curve to the northeastern base of the White River plateau which is a spur of the Park Range. It is not a conspicuous geological feature, but the reality of its existence is plainly apparent on investigation. Its vertical displacement, although considerable, is comparatively slight; and the strata involved are, in Axial Basin, partly covered from view by those of the Brown's Park group. It also becomes somewhat indistinct at its eastern end in consequence of the confusion of dips upon approaching the foot hills of the Park Range, and of the presence there of basaltic outflows. Its general character is shown by Fig. 60, representing a section across it about five miles eastward from Yampa Mountain.

Upon this inceptive portion of the Uinta fold there have been imposed two extraordinary geological features, namely, the June-

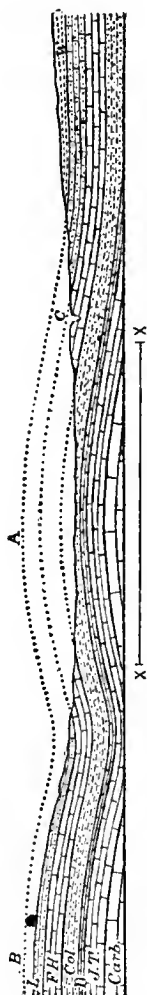


FIG. 60. Section across Axial Basin, 5 miles east of Yampa Mountain, showing the inceptive portion of the Uinta fold, and a part of the Danforth Hills uplift.

A, axis of the inceptive fold; B, north base of Danforth Hills, showing a portion of that uplift; C, Yampa River; Carb., Carboniferous strata; J.T., Jura-Trias; D., Dakota group; Col., Colorado group; F.H., Fox Hills group; L., Laramie group; W., Wasatch group. The line xx indicates proportionally the longer diameter of the Yampa Mountain upthrust, and approximately its position with reference to the inceptive axis. Horizontal scale, 4 miles to the inch; vertical scale, $\frac{1}{2}$ inch to 1,000 feet.

tion and Yampa Mountain upthrusts,¹ which I regard as the result of localization, or a locally intensified application of the force by which the fold was elevated, and which will now be considered.

JUNCTION MOUNTAIN UPTHURST.

Going only two or three miles eastward from the eastern terminus of the main fold, where we have seen the later formations dip so suddenly from view, we come to the western border of Junction Mountain upthrust. Here we find the same strata rise again, even more suddenly than they disappeared; and we also find that the formations of Paleozoic age, which constitute the high mountain peaks of the Uinta Range only a few miles away, are here again uplifted, not only to the surface of the low land around the mountain, but to a maximum height of nearly 2,000 feet above it. The strata involved in this uplift (which, because of its sharply defined limits, and of the extent of vertical displacement of those strata, I have called an upthrust), occupy an elongate oval area the extreme longer diameter of which is nearly 12 miles, and the shorter about 4 miles. The direction of the longer diameter, being approximately northwest and southeast, is obliquely transverse to the general trend of the axis of the main fold. In this respect, as well as by the peculiar character of displacement of the strata involved, the isolation of this upthrust is quite complete, although it lies so near the terminus of the main portion of the Uinta fold and upon the axis of its inceptive portion.

So sharply have the strata been uplifted in this displacement that they are either faulted or are nearly or quite vertical at a portion of each side of the upthrust; and they also dip very abruptly at other portions, and around its ends. The Mesozoic formations through which the older ones were forced lie around the mountain, but immediately adjacent to it they are largely covered from view by the strata of the Brown's Park group, which lie unconformably upon them. The disturbance which those Mesozoic formations have suffered in that neighborhood beyond the base of the mountain is so slight that one can not recognize it as having been connected with the upthrust movement. That is, their position as marking the presence of the inceptive fold and certain subordinate uplifts does not seem to have been changed by the localized upthrust movement.

¹ In using the terms "uplift" and "upthrust," I do not ordinarily intend to express an opinion as to the actual direction of the movements by which the strata were displaced; but in describing displacements it seems to be more natural to assume that the lower mass, which is the larger, was the fixed one; and that the higher, which is relatively the smaller, was uplifted. The former term needs no explanation in such a connection. The latter term is peculiarly applicable to the character of the displacements by which Junction and Yampa Mountains are characterized, as will appear in connection with their description.

The Mesozoic formations which must necessarily have risen upon the top of the older ones within the upthrust area have been removed by erosion as has also a large part of the full thickness of the carboniferous strata which came up beneath them. Therefore, only strata of Paleozoic age now enter into the structure of the mountain proper, while the upturned edges of the later ones, where they have not been sharply severed by faulting, lie around its base.

YAMPA MOUNTAIN UPTHURST.

Going from Junction Mountain about 16 miles, along the axis of the inceptive fold, we pass all the way over the low lands of Axial Basin, the surface of which is there mostly occupied by the Brown's Park group, and reach Yampa Mountain, which rises directly upon that axis, as does Junction Mountain. Here we find that the description which has just been given of the Junction Mountain upthrust will apply in all essential respects to this. All around the base of Yampa Mountain the strata of the Brown's Park group cover the immediate borders of this upthrust, even to a greater extent than they do those of Junction Mountain upthrust; but it is readily seen that the two mountains are essentially identical in structure and character, and that they have been produced in a similar manner. Yampa upthrust, however, is smaller than the other, and it is also much farther away from any other much-displaced strata. Its outline is oval, the longer diameter, including all the strata involved, not much exceeding seven miles in length, and its shorter diameter is less than four miles. The longer diameter is nearly at right angles with that of Junction Mountain upthrust, and it is nearly transverse with the inceptive portion of the Uinta axis, upon which it rises. The relation of these two upthrusts to each other, and to the main and inceptive portions of the Uinta fold, is indicated by the section, Fig. 61.

The amount of vertical displacement is about the same in each of these upthrusts, the extent of which is estimated from the thickness of the formations as given in the foregoing table, and from the contour lines on the published topographic maps of that region. The contour line which cuts the top of the Uinta Quartzite in both these mountains passes along the southern side of Axial Basin approximately at the base of the Laramie and top of the Fox Hills group. Referring to the preceding table we find the thickness of the intervening formations to be 11,800 feet. It is plain, therefore, that the amount of vertical displacement in both these mountains is not less than is represented by those figures.¹ That is, within the narrow

¹ The estimate of 8,000 feet given in my report on that region (loc. cit.) was inadvertently made too small, as may be seen by the data there used, as well as by the figures in the preceding table.

and sharply defined limits that have been described, the strata of which both these mountains are composed have been thrust up a vertical distance of more than two miles; which, in the case of the Yampa upthrust, is nearly equal to one-third the longer diameter of the area affected by it.

As indicating that the amount of vertical displacement in these upthrusts is really greater than has been mentioned, it may be stated that the Fox Hills and Laramie strata referred to have themselves been elevated to a considerable extent in the adjacent Danforth Hills uplift, as shown by the section, Fig. 60. This figure will also serve to illustrate the relation of the Yampa upthrust to the inceptive fold, and to the adjacent Danforth Hills uplift. That is, if within the space indicated by the length of the line *x, x*, the strata should be elevated until the base of the carboniferous series reaches the place of the uppermost dotted line, the vertical extent and lateral restriction of the Yampa upthrust will be indicated.

RELATION OF THE UINTEA FOLD TO OTHER FOLDS AND TO THE PARK RANGE UPLIFT.

It is true that the vertical displacement in the case of the two upthrusts is much less in amount than is that of the great fold; but the amount of displacement is far more remarkable in the case of the upthrusts than it is in the case of the fold, because of the very narrow limits within which the displacements in the former case have taken place. The narrow and sharply defined limits of these upthrusts, and the severing of the displaced portions of the formations from the great mass of each respectively, with little or no general disturbance of the latter beyond those limits, may be compared to the action of a large punch on being forced by great power through a number of thick iron plates. The comparison will be more complete if we conceive that the cutting border of such a punch had become

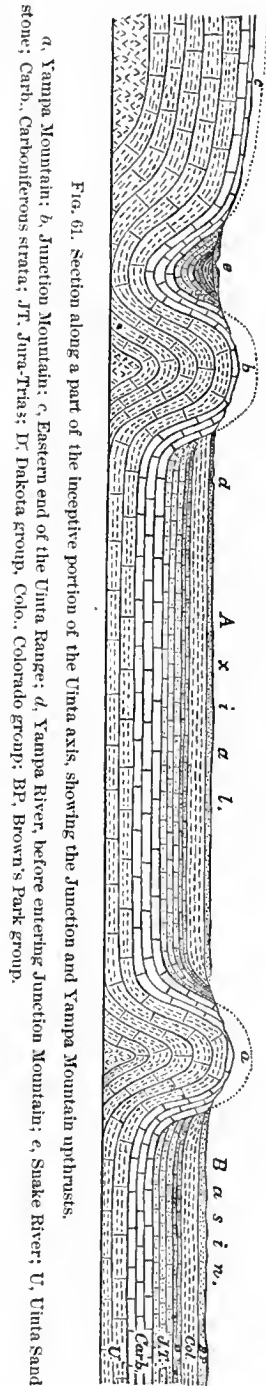


FIG. 61. Section along a part of the inceptive portion of the Uineta axis, showing the junction and Yampa Mountain upthrusts.

a, Yampa Mountain; b, Junction Mountain; c, Eastern end of the Uinta Range; d, Yampa River, before entering Junction Mountain; e, Snake River; f, Uineta Sandstone; Carb., Carboniferous strata; JT, Jura-Trias; D, Dakota group; Colo., Colorado group; BP, Brown's Park group.

dulled at certain places so that a part of the iron through which it was being forced would drag, and not be sharply severed. Portions of the uplifted strata at the base of both these mountains seem to have thus dragged during their elevation, while other portions were sharply severed as if the displacement had really been done by a huge punch acting from beneath; producing, of course, an ordinary fault there.

Referring to the fact that the two upthrusts have taken place upon the axis of the inceptive portion of Uinta fold, and apparently after that portion had reached its present stage, it is well to turn aside for the moment to notice further certain other phenomena which are correlated with this, and to consider their probable significance. The phenomena referred to indicate that while the displacements now observable in that region were in progress there were many local arrests and accelerations of the elevating movement which produced a final diversity among them that did not exist in their inception. For example, the present structural condition of the Uinta fold seems to warrant the assumption that it was once, along its entire length, in the condition in which the inceptive portion now is; except for the presence of the two upthrusts; furthermore, that these upthrusts, as well as the main portion of the fold, continued their upward progress while what I call the inceptive portion remained as it was when its elevation was arrested.

Again, it may be assumed that the subordinate folds adjacent to the eastern end of the main Uinta fold all had an approximately equal start with the latter, but that the final extent of the upward movement was different in each case. For example, when the Midland fold ceased to rise the elevation of the others continued. Then the rise of Yampa Plateau fold ceased, while that of the great fold continued until its completion. These successive steps are well indicated in the section, Fig. 59.

The elevating force was not only strangely concentrated in the case of the two upthrusts, but it seems to have been applied in an unusual manner, especially when we consider the position of the longer axis of each with relation to that of the other, and also to that of the Uinta fold. It has been mentioned that the direction of the longer axis of the Junction upthrust is northeasterly and southwesterly. Viewing these upthrusts only in relation to the Uinta fold proper, and regarding them as nearly or quite isolated portions of the same, one would naturally expect to find their longer axes coinciding with a line projected from the axis of the main fold, and he would also expect to find the intervening strata along that line to have partaken largely in the upward movement. That is, in view of the simplicity of the main portion of the Uinta fold one might naturally expect to find evidence that the uplifting force which was applied along its entire axis would have acted with approximate uniformity. But the fore-

going statements show that neither of the axes of the two upthrusts coincide with such a line or with each other. Also, that only a slight elevation of the strata has occurred along the inceptive portion of the Uinta fold, as compared with that of the main portion and with the upthrusts.

While the Danforth Hills uplift holds an intermediary relation to both the Uinta and Park ranges, it seems natural to regard the two upthrust mountains as outlying members of the Uinta Range, and there also seems to be no sufficient ground for doubt that both upthrusts were produced as a part of the orogenic movements which resulted in the final completion of the Uinta fold. Still, the relative position and the peculiarities of these upthrusts are such that it is evident they ought to be studied, not with reference to that fold alone, but also with reference to the Park Range of the Rocky Mountain system. Such a study not only reveals the existence of an intimate relationship between the two great ranges, but it discovers evidence that both of them, together with their subordinate folds, their spurs, and the two upthrust mountains, are all the results of one great system of orogenic movements.

A part of the facts showing the relationship of the Uinta to the Park Range has already been mentioned, and in support of this view the following remarks may be added: A large irregular spur of the Park Range, known as the White River Plateau, reaches within the limits of this district. In this plateau, a large part of which is shown on the lower right hand portion of the accompanying map, the Carboniferous rocks are brought to view as they are in the Uinta Range and in the two upthrusts. Along its western base also the same Mesozoic formations which are upturned at the base of the Uinta Mountains are there upturned, and their outcrop thus formed extends far southward along the western flank of the Park Range. The Fox Hills and Laramie strata thus upturned constitute what is known as the Great Hogback.

A part of these formations, less abruptly upturned, may be traced by a broad curve continuously across the intervening space between the two ranges from the western base of the White River Plateau to the southern base of the accessory folds of the Uinta Range. The general trend of these upturned formations approximately corresponds with that of the inceptive portion of the Uinta axis, but it is somewhat modified by the presence of the Danforth Hills uplift. Their dip also corresponds with the comparatively gentle elevation of the inceptive fold, and there is almost nowhere any indication that either the dip or trend has been affected by either of the two upthrusts.

With the two great mountain folds rising by simultaneous stages at right angles with each other and serving as ponderous buttresses on either hand, it is not strange that any elevating force which may

have been exerted along and at either end of the intervening space should have been diversely, if not abnormally applied. The results of this diversity in the application of elevating force are conspicuously seen in the extraordinary cases of its local restriction; in the diverse positions of the resulting subordinate axes, and in the varying heights to which closely adjacent vertical displacements have reached, all of which have been discussed on preceding pages. An explanation of the mode of origin of these phenomena ought doubtless to be sought in connection with studies in dynamic geology, to complete which would lead the investigator far beyond the limits of the district specially considered in this article.

CANONS TRAVERSING THE UPTHRUSTS AND FOLDS.

The phenomena described on the preceding pages are certainly of great interest, and a part of them are very remarkable; but some of those which are now to be described, and which pertain to the second of the categories mentioned in the opening paragraph of this article, are, if possible, still more remarkable. Those now to be considered have reference to the corrasion of the valleys and cañons of the rivers which traverse the same region, and a part of which cut through the uplifts that have been described.

To most persons it would seem natural to infer that the rivers which traverse a mountain region would flow through the low lands, avoid the mountains, and pass around the end of the ranges rather than through them. This region, however, presents remarkable examples of an entirely different character; that is, the principal rivers here flow in narrow cañons along a part of their course, which they have themselves evidently cut. Not only is the eastern portion of the Uinta Mountain Range traversed in different directions by such cañons, with the rivers at the bottom, but isolated mountains surrounded by low lands are similarly traversed in the same region. Even when taking into consideration the geological structure of a region, it would not seem unnatural to suppose that the rivers would generally be found to run in synclinal valleys between such folds of the strata as may have been elevated in their vicinity. It is true that a river within this region is sometimes found to occupy a synclinal valley for a short distance; but such cases are rare, while we find numerous examples of rivers traversing such elevated folds as have been described. Indeed, these rivers traverse the folds in such directions, and occupy such positions in relation to them, as to show that the folds have exerted little or no appreciable influence on the location of the rivers.¹

¹ All the various conditions of drainage with its relation to the underlying geological structure, which occur in this region, have been fully described and discussed by Powell in his *Exploration of the Cañon of the Colorado*, pp. 160 to 166, to which the reader is referred.

The streams which drain this district, as before mentioned, are Green, Yampa, Snake, and White Rivers, the latter traversing only a portion of its southern border. After leaving the foot-hills of the Park Range, White River reaches its confluence with the Green without having cut any important cañons in either the Great Hogback or the Raven Park fold, both of which uplifts it traverses. It has, however, cut some interesting cañons through the Tertiary strata along other portions of its course; but as these are of somewhat different character from those to which I shall especially refer they need not now be discussed.

Snake River, after receiving the waters of its main tributaries from the foot-hills of the Park Range, flows southwestwardly through comparatively open country to its confluence with the Yampa without traversing any conspicuous uplift of the underlying strata in its course. It even passes closely around the northern end of Junction Mountain and reaches its confluence with the Yampa in Lily's Park through the narrow strip of low land (which is a true synclinal valley) between that mountain and the eastern end of the Uinta Range. In short, it follows such a course as those unacquainted with other conditions would naturally expect a river to choose. But in this respect Snake River is really an exception to the general rule which is applicable to the other rivers that traverse this district, as will be seen by the following remarks on the cañons of Green and Yampa Rivers.

It is true that the course of both Green and Yampa Rivers is in large part through open country, or through lands that are not mountainous, where they have had only the later and softer formations through which to cut their way. But while peacefully flowing along such portions of their course they often strangely leave these seemingly favorable positions to traverse mountains or other elevations which in most cases are composed of harder strata than those over which the rivers had previously been flowing. In traversing these mountains also they almost invariably do it by narrow cañons, the walls of which are often nearly or quite perpendicular, and of great height.

THE UINTA CAÑONS OF GREEN RIVER.

Green River flows southward through the central portion of the Green River Basin, towards the eastern portion of the Uinta Range of mountains which lies directly across the river's course. Upon reaching the foot-hills the river at once passes through them and enters the northern side of the range. Here, after making a sharp bend in what is called Horseshoe Cañon, as if it were about to return upon itself, it sweeps by another bend further into the range and pursues its course for a long distance through deep, narrow cañons. After the river has reached well within the range it turns suddenly eastward, its course now being through Red Cañon, which lies nearly

parallel with the axis of the Uinta fold. From this cañon it emerges into Brown's Park, the low lands of which it traverses for a distance of about 25 miles, its general course there being a little to the south of east. A less distance farther in that direction would have carried it over similar low lands to the eastern terminus of the Uinta Range, around which, and then southward, the low lands continue. Instead of availing itself of this seemingly favorable route to reach the southern side of the Uinta Range, where lies its destined course, the river leaves Brown's Park at the point indicated, and turning suddenly southward it re-enters the Uinta Range by the "Gate of Lodore," which is the northern end of the narrow cañon by which the river traverses the whole width of the Uinta Range. The cañon walls of the Gate of Lodore rise abruptly from the river and from the south side of Brown's Park, where they are more than 2,000 feet in perpendicular height above the river; and some of the higher points near and along the course of the cañon are fully 1,000 feet higher.

After traversing the whole width of the main range, the river emerges into the short, narrow, synclinal valley between Split Mountain and the main range. This valley, as has already been shown, communicates with the low lands which lie toward the south, the direction in which the river finally flows. But instead of pursuing its way by this apparently favorable route the river enters Split Mountain, cutting entirely through it, and leaving its cañon walls of hard rock towering on either hand to the dizzy height of nearly half a mile. Then, and not till then, does the wayward river consent to go on its quiet course through the open country towards its junction with Grand River, where its waters, mingled with those of that river to form the Colorado, flow through still more profound and remarkable cañons beyond.

YAMPA MOUNTAIN CAÑON.

The course of Green River across the upfolded Uinta Range, which consists there wholly of the hard strata of the Paleozoic formations, when apparently it might so easily have gone around it upon low lands and have made its channel through softer formations, is so remarkable as to arrest the attention of every observer. But the Yampa is perhaps the most remarkable of all the rivers in that region with reference to their seeming disregard of favoring conditions of location. This river rises by numerous tributaries among the mountains of the Park Range, where it has a turbulent course of many miles through rocky defiles and narrow valleys. Then emerging from the foot-hills of the range, it traverses the open country which lies toward the west, its general direction being toward the eastern end of the Uinta Range and along the greater part of the length of Axial Basin. This latter part of its course; being approximately upon the axis of the ineptive portion of the

Uinta fold, Yampa and Junction Mountains lie directly in its way, while around these mountains lie the low lands already described.

Upon reaching Yampa Mountain, the river, in almost seeming wantonness, cuts its way by a short cañon through the hard Paleozoic rocks which form the northern flank of the mountain, making a small bend into its mass, instead of swerving a little in the other direction and passing at its northern side upon the low land there. This cañon, compared with others in that region, is insignificant, for it is very short and its walls are only from 600 to 800 feet in maximum height above the adjacent low lands; but considered in connection with the geological structure beneath, it is very remarkable.

JUNCTION MOUNTAIN CAÑON.

From Yampa Mountain the river flows quietly over the low lands of Axial Basin to Junction Mountain, which it cuts through in a similar manner. As one stands upon Junction Mountain and looks out over the broad low land which lies adjacent to its northeastern side and is continuous with Axial Basin toward the east and with Brown's Park toward the west, the opportunity seems especially favorable for the Yampa to have reached the further side of Junction Mountain by joining Snake River near the northern end of the mountain. Indeed, for more than half its course after leaving Yampa Mountain the river trends in that direction as if it were destined to go there; but instead of doing so, it makes a distinct bend southward, goes direct to Junction Mountain and cuts off its southern end, as it had already cut off the northern end of Yampa Mountain. The strata of hard rock, which are upturned like a broken dam at the foot of the steep mountain side, constitute no impediment to the course of the river, and without swerving to the right or left it enters the mountain and traverses it by a narrow cañon, the almost perpendicular walls of which reach a maximum height of from 1,000 to 1,200 feet above the low land at either end of the cañon.

YAMPA CAÑON.

After having traversed Junction Mountain, the river has a peaceful course of eight or ten miles through Lily's Park, which is merely a broadening of the valley, where it receives the waters of Snake River. Then, instead of joining Green River by way of the low land at either the northern or southern side of the Uinta Range, it boldly enters its eastern end, crossing the upturned strata there as it had done in the former cases. From here the remainder of the river's course is through a narrow cañon, which, for a large part of its length, is fully 1,200 feet deep, and which joins the cañon of Green River before the latter emerges from the southern side of the range.

The distance from end to end of Yampa Cañon, in a straight line, is about twenty miles. While it meanders to some extent, its general course is direct, and coincides approximately with the axis of the Uinta fold. That is, the narrow cañon has been cut perpendicularly into, and mainly along the strike of, the hard Carboniferous strata, where they have their southerly dip in the southern flank of that fold. In short, the position and direction of the river are such with relation to the dip and trend of the strata there that no indication is apparent that the latter have had any influence in determining the former.

CONCLUDING REMARKS.

If the phenomena relating to the river cañons of this district which have just been described were considered without reference to, or any knowledge of, a geological history of the region in which they occur, they would be wholly inexplicable; but considered with reference to that history, their origin is easily explainable. And yet, with all the relevant facts in mind, even he who is accustomed to weigh and consider such evidence is often amazed at the results which have been produced by the forces which are and have always been in constant operation upon the face of the earth.

The following summary statement of the origin of these phenomena is given in a few words, but a careful examination of Powell's elaborate statement of the subject (*op. cit.*), should not be omitted.¹ The rivers of the region occupied the surface before it was elevated to any considerable height above the level of the sea, and before the region was greatly disturbed by orogenic movements. When the uplifts were formed in which the mountains originated, the rivers refused to yield "the right of way."² That is, the rivers were

¹ This subject is also well stated by Dutton in the Second Ann. Rep. of the Director of the U. S. Geol. Survey, pp. 60-63.

² The theory is entertained by some geologists that the later formations completely mantled the whole region after the great displacements which have been described occurred, and after resulting mountains and other great topographic features were produced. Further, that the present drainage system was established upon the surface of those later formations, and that the streams have dropped to their present levels as the surface of the region gradually became degraded by erosion. Such a theory requires—

(1) That the present drainage system of which the Colorado is the principal channel was established after the close of the Tertiary period.

(2) That this system was established upon a land surface the lower portions of which were then at an elevation little if any less than 10,000 feet above the level of the sea, a large part of it at a still greater elevation.

(3) That to give the requisite amount of drainage water to produce the vast erosion and corrasion which have taken place there, the geographical extent of that greatly elevated region must have been quite equal to that which is now drained by Green River and its tributaries.

The possibility that such conditions could have existed seems inadmissible.

established in a large, comparatively plain region, which they drained, their location having been determined by conditions then prevailing. Subsequently, movements of the earth's crust took place in the same region, resulting in broad elevations and in elongate folds and locally restricted uplifts, the material of which, after great erosion, became respectively the high plateaus, mountain ranges, and isolated mountains or mountain clusters which now exist. When the later part of the elevation of the great Plateau Province took place its pre-existing drainage system was necessarily raised with it to some extent, so that their river beds are now at a higher level above the sea than they originally were. But this elevation of the river beds has been little as compared with that of the present land surface, and especially so if compared with the amount of vertical displacement that has taken place there since the rivers were first established, because the rivers have maintained a comparatively low level for their beds by cutting deep cañons in the rising land.

When a fold like that of the Uinta Range, for example, began its elevation across or along the course of one of these rivers, the corrasive action of the latter was immediately exerted upon the threatened obstruction, and overcame it regardless of the hardness of the uplifted rock, and this action did not cease or fail in its effect as long as the elevation continued. This corrasive action of rivers is, indeed, very slow; so also has been the movement of elevation, the one having balanced the other even through thousands of feet of vertical elevation of the underlying rocks. In view of the stupendous effects of the action of these two forces which may be witnessed in the cañons of the region here discussed, and in the still grander cañons of the Colorado, one becomes impressed with the immensity of the results which may be accomplished by slowly acting forces through long periods of time.

Not only were the rivers not checked in their flow when mountain folds were elevated athwart their course, but they refused to be thrust aside by such folds as may have been raised either directly or partially beneath them with the direction of their axes coinciding more or less nearly with that of the river's course. The longer cañon of Yampa River, upon the southern flank of the Uinta fold, and Red Cañon of Green River, upon its northern flank, are examples of such cañons as have been cut in a direction approximately parallel with the axis of a fold which has been elevated from beneath them, while the direction of Lodore Cañon, of the latter river, is transverse to the axis of the fold.

But, since these longer cañons traverse broad folds and elevated areas, it may be suggested that the rivers which produced them were less liable to be swerved from their original courses by the vertical movement which took place beneath them than they would be in the

case of the rising of narrow folds and of such upthrusts as have been described. But the facts already presented show that the elevation of not only the narrowest folds, but even that of the two upthrusts which have been described did not cause the rivers under which their elevation began to swerve from their original courses as the elevation progressed, to the extent of more than a few rods. This fact is exemplified in Split Mountain, where Green River cuts a short, deep cañon through that prominent spur of Yampa Plateau; but it is more conspicuously shown where Yampa River traverses both the Junction and Yampa Mountain upthrusts.

I am sure that the phenomena described on the foregoing pages merit the statement made in the opening paragraphs of this article that they possess peculiar interest; but, among them all, none are more likely to permanently impress the reader than those which are connected with the two upthrusts and the short cañons which traverse them.

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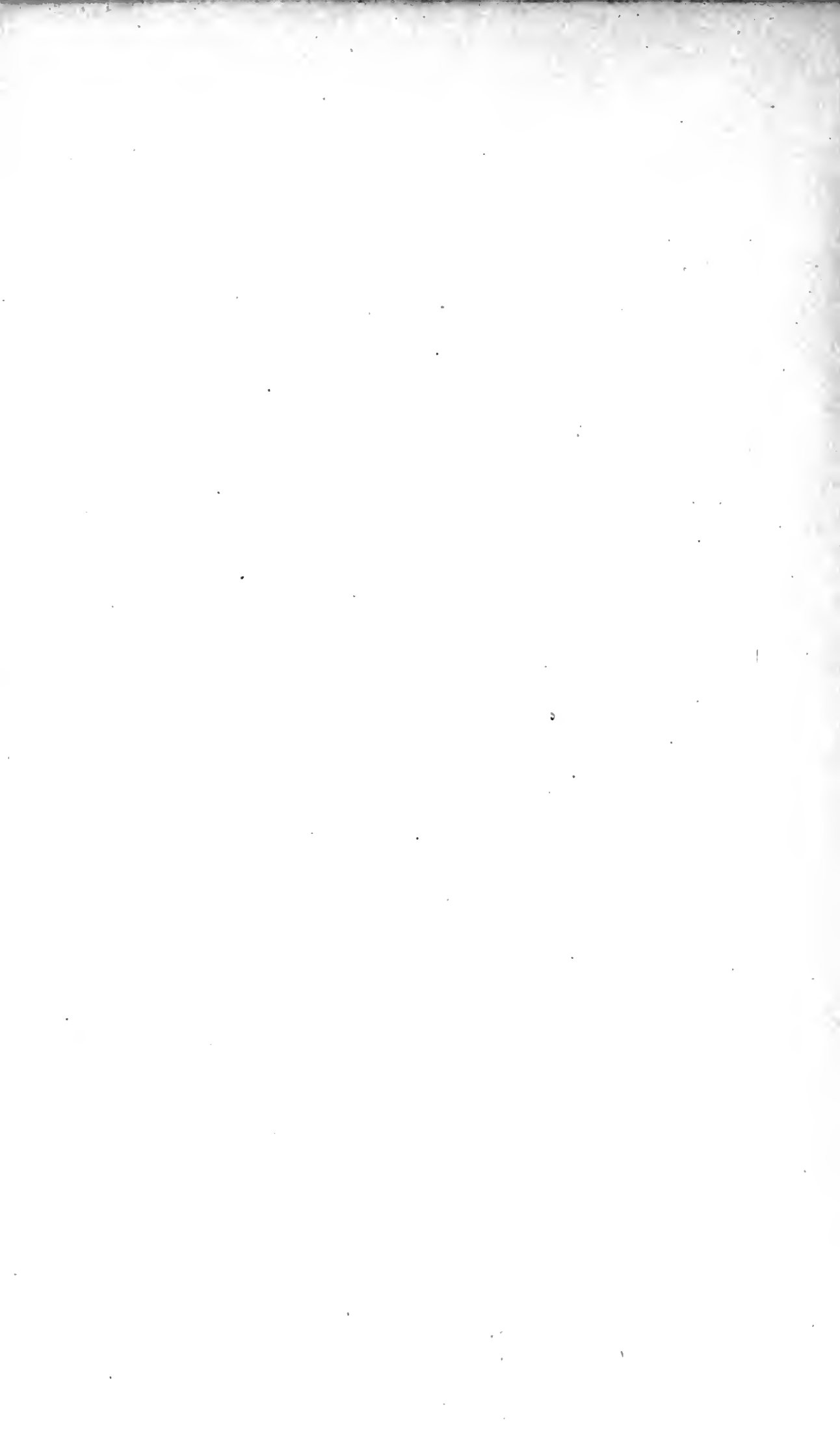
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